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ZnO Nanostructures Grown by RTCVD; Suitable for Various Applications

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Abstract—*Various ZnO nanostructures have been synthesized using the RTCVD method. The nanostructures varies from nanocrystals to aligned bunches of nanowires. These kind of bunches of aligned nanowires are suitable for device applications such as LEDs, sensors, optical devices etc.. The XRD results reveal the wurtzite hexagonal phase of ZnO. Raman studies confirm the impurities and oxygen deficiency present in the investigated samples.*

Index Terms— *RTCVD, Nanostructures, ZnO*

1. INTRODUCTION

Various techniques have already been used for the synthesis of zinc oxide nanostructures, suitable for various device applications such as sensing devices (gas, chemical and biosensors), transparent conductors in solar cells, opto-electronics and light emitting devices as well as in high-power electronics[1,2]. Due to the optical and electrical properties of ZnO nanostructures, these are also used as ultraviolet UV devices, photodetectors, piezo-transducers, hydrogen storage, as well as spintronic devices. Various ZnO nanostructures are already reported in the literature synthesized by different methods like solution method, hydrothermal method, sputtering, thermal evaporation, having focus either on studying the properties of the synthesized materials or on the application in different forms. Amongst these, aligned one dimensional (1D) ZnO nanowires/nanorods are demonstrating superior device properties with high carrier mobility compared to that of non-aligned ZnO nanostructures. ZnO nanowires and nanorods are recently explored for the optoelectronic devices due to high band gap and therefore is the focus of the interest. ZnO has a key feature of large excitonic binding energy (60 meV) and high optical gain of 300 cm^{-1} at room temperature which results in an efficient and extreme stable excitonic emission at room temperature (RT) and promising to various applications. Therefore, we choose to study the morphological variation and structural properties of ZnO suitable for device application such as LEDs deposited by RTCVD, and also for size dependent optical properties and optoelectronic applications.

2. EXPERIMENTAL DETAILS

Various nanostructures of ZnO were prepared using the rapid thermal chemical vapor deposition (RTCVD). Pure Zn (99.9%) was evaporated in oxygen ambient. RTCVD set up was constructed by modifying the thermal evaporation system with a small sub evaporation chamber of quartz tube (25 mm diameter and 120 mm length). The set up was open for evaporation source, sample holder, gas inlet and gas outlet as shown in Fig. 1. With the quartz tube we were able to confine the evaporated material and maintain the uniform oxygen pressure in the vicinity of the evaporation source. Mo-boat containing Zn powder was encapsulated in quartz tube sub-chamber and whole assembly was enclosed in the vacuum chamber. After loading the substrates and source material, chamber was evacuated to 10^{-5} Torr then 0.1 Torr oxygen was injected into the sub chamber and this oxygen pressure was maintained throughout the evaporation. Source temperature was varied from 600^0C to 700^0C which resulted in varying morphologies and structure variations. The deposits on the quartz tube were collected and were analyzed for elemental and structural properties. Each sample was prepared, separately, keeping a constant temperature at 0.1 Torr oxygen pressure inside the tube.

X-ray diffraction measurements were performed using Bruker D8-advance diffractometer with CuKα radiation (λ= 1.542 Å) for the Bragg angle ranging from 20 to 80 degrees. Scanning electron microscopic (SEM) images were obtained using JEOL (JSM-6380) electron microscope. Raman scattering spectra was obtained using LabRam HR800 JY with He-Ne source (λ =632.8 nm) and beam diameter of 1.2 μm operating at fixed laser power of 2 mW and scanning range of 200–650 cm^{-1}.

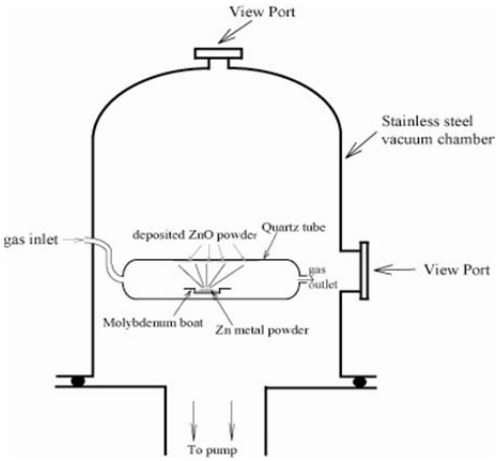

Fig. 1 Experimental set up of RTCVD system used for the growth of ZnO nanostructures

3. RESULTS & DISCUSSIONS

Fig. 2 depicts the X-ray diffraction patterns of ZnO nanostructures grown as a function of deposition temperature (600 to 700^{0}C). The variation in peak intensities with temperature is observed. The observed peaks matched well with the standard peaks related to the JCPDS files (36- 1451, 21-1486, 01-1136), which are of wurtzite hexagonal phase. The presence of intense peaks reflects good crystallinity of grown ZnO powder. The peak intensity related to (002) plane increased with increasing deposition temperature indicating that orientation is unaffected by the growth temperature, whereas the intensity of other peaks related to (100), (002), (101), (102), (110), (103), (112) (201) (004) and (202) has changed. The peak related to (110), (002), (101), (102), (110), (103), (200), (112) and (002) exhibits low intensity.

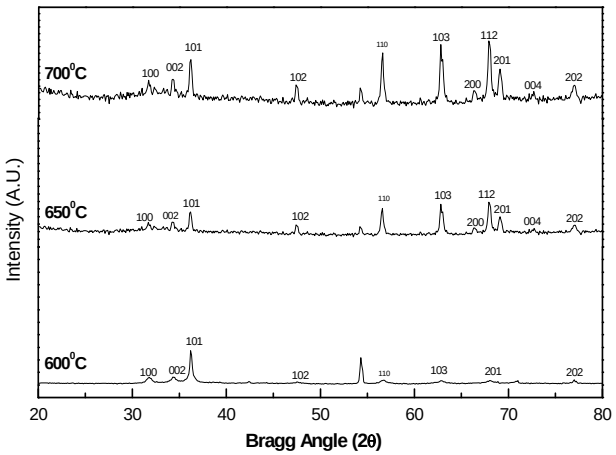

Fig. 2: X-ray diffraction patterns of ZnO nanostructures

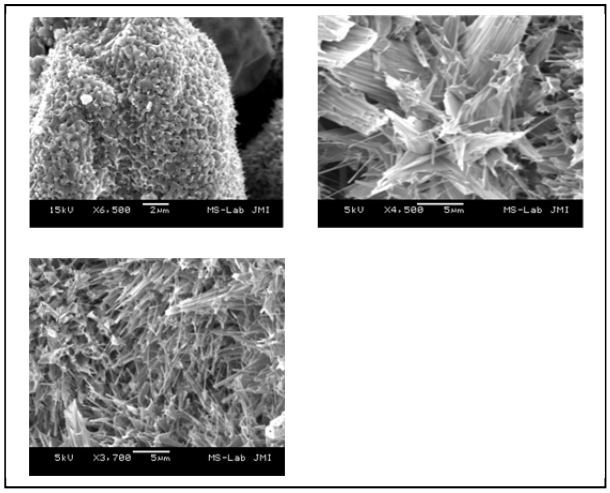

Fig. 3: SEM Images of ZnO

Fig. 3 reveals the SEM images of the ZnO nanostructures as a function of deposition temperature. At 600^{0}C very fine nanocrystals of ZnO having diameter range from 90-150 nm are grown. Further increasing the temperature to 650^{0}C, bundles of nanowires having diameter of 10-20 nm and of few microns in length have been observed. These bundles of nanowires are seems to be arranged vertically. At 700^{0}C these bundles of nanowires become separated which can be seen clearly in SEM image.

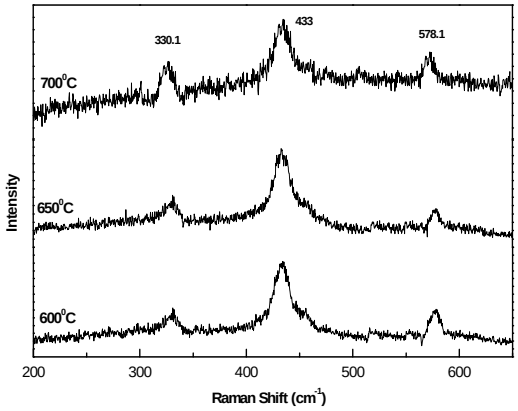

Fig. 4: Raman spectra of nanostructures

Raman spectroscopy study was carried out as it is sensitive to the morphology and size of the nanostructures. The spectra of the samples are shown in Fig. 4. The Raman spectra show three different peaks around 330 cm^{-1}, 434 cm^{-1} and 578 cm^{-1} which suggest the presence of wurtzite ZnO phase. The peaks positions slightly differ for each sample depending on structure or deposition conditions. There are three types of peaks observed; (i) a suppressed and broad peak around 326.5 to 330 cm^{-1} is of lower E2 and related to the multiple photon

scattering processes. (ii) A most dominant phonon peak for all samples is about 433–435.1 cm^{-1} is the E2 high peaks associated with oxygen atoms. (iii) a comparatively symmetric peak about 572.5 to 578 cm^{-1} of E1(LO) modes. Presence of E1(LO) peak reflects the impurities, oxygen deficient sites and Zn interstitial sites exists in the grown nanostructures.

4. CONCLUSIONS

In summary, we have grown various ZnO nanostructures like aligned bunches of nanowires, nanocrystals, and nanowires by varying the growth temperature, at 0.1 torr constant oxygen pressure in the chamber during rapid thermal evaporation. XRD, SEM and Raman were used to characterize the grown nanostructures.

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